Practical Electronic Instrumentation for All Engineering Disciplines

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ABSTRACT

True engineering is a multi-discipline field and commonalities exist among all types of engineers. Engineers work within their environment and control processes by using instrumentation in order to sample surrounding physical phenomenon such as light level, temperature and pressure. Electronic Instrumentation Systems are concerned with data acquisition, signal processing and computer control. In these systems, data acquisition circuits use sensors and signal conditioning electronics in order to convert physical environmental changes into electric signals that can be processed with a computer.

Gaining experience with practical electronic instrumentation is an important experience for any engineering student and should be a part of a rounded engineering education. Design is a major component of the course described in this paper, therefore the course complies with the American Board for Engineering Technology (ABET) requirement that the design process should bean integral part of the engineering curriculum. The material learned in this type of course can be immediately applied to independent design projects and these skills can later be used in professional work. This paper describes the process of introducing practical electronic instrumentation to non-Electrical Engineers.

I. Introduction

The tasks performed by engineers and scientists are often concerned with sampling and affecting the current state of the working environment. A Chemical Engineer, for instance, may make measurements of process parameters in order to control a reaction. A Mechanical Engineer may design a control system for a mobile robot that would affect the machine's position in the world based on the objects sensed in its path. These instrumentation measurements are made by deploying sensors in the working environment. The sensors provide an electric signal that changes in response to the physical surroundings. This electric signal is conditioned and then analyzed. If specific circumstances are met, then the devices that are being controlled are adjusted to react to the new environmental conditions. The whole task is often automated and put under closed-loop computer control.

The curriculum at many institutions gives engineering students the opportunity to learn the very basic principles of electric circuit theory. The material taught in the course described in this paper makes the next step: teaching students the necessary tools to evaluate and design the instrumentation systems that will become their trade tools as engineers. This course fills an immediate need of many students, giving them a background for upper-level design courses and it also serves to prepare students for professional work. This paper describes the . process of introducing practical electronic instrumentation skills to non-Electrical Engineers.

The course, *Electrical Instrumentation and Measurement,* taught through the Electrical Engineering Department at the United States Naval Academy (USNA), is a one semester elective course that meets twice a week for an hour in class and for a two hour laboratory period. The main emphasis in the course is on laboratory work. Class time is spent exploring the interaction between the components in an instrumentation system and the theory behind the physical changes that take place in sensing devices. Theses concepts are tested and validated in the laboratory design work.

II. Course Objectives

The intended audience for this course is the non-Electrical Engineering student. Most engineering students take some introduction to basic electric circuit analysis, DC and AC circuits, therefore this course is not meant to be another Electrical Engineering circuit theory course. Some of the books used in the basic circuit analysis courses at the USNA are listed in the Bibliography section of this paper [1,2].

This course was developed to meet a need expressed by members of Physics, Chemistry and the Engineering Departments at the USNA, to provide a course that applied the circuit theory material to the next level. Most of these students will be involved with Capstone Design projects and will be expected to develop sensor circuits that *bring machines to life.* Therefore, the objective of the course is to expose students to the building blocks of an instrumentation system. The topics covered in the course come from the components that make up a general instrumentation system as shown in Figure 1. The major topics presented in the course are grouped into three sections: Signal Conditioning Circuits, Sensors and Transducers, and Computer Interfacing.

III. Course Topics

The goal is to present the course material in such a way that the student gains both analytical and design skills. The emphasis is directed toward addressing real world engineering problems. Some of the text book and reference material recently used in this course are listed in the Bibliography section [3,4,5].

In the laboratory exercises, the students are expected to design circuit components that meet given instrumentation system specifications. For instance, a lab may be organized so that the student explores some circuit theory, then applies these new skills to a design problem. The purpose of this is the belief that the student must apply what has been learned in order to truly understand the concept. This process also complies with ABET design requirements. Text books that have been used in the course to enhance the design process are listed in the Bibliography section [6,7].

The laboratory equipment requirements for this course are the same as for any basic circuit analysis laboratory. Required equipment consists of a DC power supply, signal generator, meters (voltmeter, ammeter, ohmmeter), oscilloscope, circuit components (resistors, capacitors, inductors), sensors according to topics listed in Section III B, breadboard, and digital chips according to topics listed in Section III C.

A. Signal Conditioning .

The course begins with a discussion of signal condition circuits. By using this as the starting point for the class, any necessary review in circuit analysis can be accomplished early in the semester. Again, it is worth repeating that this course is not a circuit theory course. Students learn basic techniques for signal modulation and filtering. Discussion time is spent on determining how these circuits are appropriately applied to a system.

Referring to Figure 1, the signal conditioning module takes the electrical signal from the sensor and makes any necessary modification before this signal is passed on to the next module. For instance it may be necessary to change the magnitude range of the signal to coincide with the input/power requirements for the next stage, or the signal may be corrupted by electrical noise and perhaps it may be necessary to apply a filter.

Among the topics covered in the "Signal Conditioning" section of the course are:

- Statistical analysis of data for error identification and evaluation
- Sources of electrical noise and removal of electrical noise
- Active and passive filters
- Measurement circuits: Voltage divider, Wheatstone bridge, . . .
- Op-amp circuits
- Power analysis
- Analyzing and meeting component specifications.

B. Sensors and Transducers

One "senses" changes in the environment by using materials or combinations of materials that respond to changes in light level, temperature, pressure, etc. The course briefly addresses the material composition of sensors. The knowledge gained in the first part of the course is applied here to the design of basic circuits that convert the material change to an electric signal. Time is spent assessing the strengths and weaknesses, according to the operating environment, of various commercially available sensors. These simple sensors are then always applied to engineering problems. For instance, in one design problem, it is discussed how each sensor can be used in a system in order to determine the speed of an object.

Among the types of pure sensors discussed in the "Sensors and Transducers" section of the course are:

- Light: Visible and Infrared
- Force
- Temperature
- Hall Effect

C. Computer Interfacing

In this section of the course, students are introduced to methods by which one may automate data taking and closed-loop system control with a computer. Computer standards for serial and parallel data transfers are discussed along with commercially available devices.

Among the topics discussed in the "Computer Interfacing" section of the course are:

- Basic Digital Logic Gates

- Flip-Flops
- Counters
- Clock Rates
- Multiplexer and Demultiplexers
- A/D and D/A Conversion
- Data Busses
- Serial and Parallel Data Transmission
- UART'S

D. System Interaction

In the last part of the course, consideration is given to the instrumentation system as a whole and to the interaction of the individual modules. One of the most important topics covered in this section is timing. In an instrumentation system with multiple sensors, timing the data access is critical. If delays are inadvertently introduced into the system, the information conveyed by the sensors may not represent the actual state of the environment.

IV. Student Involvement

At the beginning of each semester, a questionnaire is distributed to the students taking the course. They are asked, "What do you expect to learn from this course?" and "What topics did you expect to see included in the syllabus and are not listed?". This gives the instructor the opportunity to slightly tune the topics presented in order to stay within the interest realm of those taken the course. All students are aware that the course deals with electric circuits, sensors and computer integration. Within these topics some students have very specific interests, such as radar as used a sensing "device" or medical sensors. These specific topics can easily be included in the "Sensors and Transducers" section and, over time, this acts as a catalyst for course development. The questionnaire also sets the stage for some thought provoking discussion. Many students are currently involved in a senior design project or are doing preliminary research to that end. Often a student has a comment or a question about a specific part of a project that fits very well into the subject matter of the course.

The *Electronic Instrumentation and Measurement* course has been taught at the USNA to students with different majors and varying backgrounds in electric circuit theory. In the two years the course has been run, it has been found that circuit design has not been a stumbling block for students. By the end of the course, each student was comfortable with electric circuit design for measurement in instrumentation circuits. The fact that the course stresses design, gives the students the opportunity to see different approaches to the same problem. Students have found the time spent comparing and contrasting design approaches, solidifies the understanding of the course material.

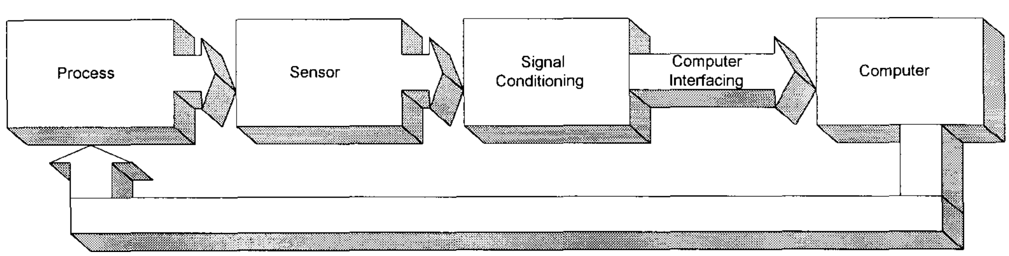

Figure 1: Instrumentation System

VI. Conclusions

This paper has described the course Electronic Instrumentation and Measurement taught at the USNA. The intended audience for this course is the non Electrical Engineering student with at least one basic course in electric circuit theory. The course looks at the components of an instrumentation system, Signal Conditioning, Sensors and Transducers, and Computer Interfacing. The course fills a need of many students, giving them a background for upper level design courses and it also serves to prepare students for professional work.

VII. Bibliography

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VIII. Biography

KELLY KORZENIOWSKI completed requirements for the Ph.D. at Brown University in 1993. Dr. Korzeniowski is currently an Assistant Professor at the United States Naval Academy, Annapolis, MD, in the Department of Electrical Engineering. Her current research work at the USNA focuses on developing controllers and algorithms for robotic systems to perform object recognition, manipulation, and exploration through sensor fusion.